PREPARATION AND MECHANICAL CHARACTERIZATION OF POLYESTER RESIN/CHINA CLAY NANOCOMPOSITES

Lutfun Naher Hilary
Department of Applied Chemistry and Chemical Engineering, Faculty of Engineering and Technology, University of Dhaka,
BANGLADESH

Ismat Zerin Luna*
Department of Applied Chemistry and Chemical Engineering, Faculty of Engineering and Technology, University of Dhaka,
BANGLADESH
***Corresponding Author**

A. M. Sarwaruddin Chowdhury
Department of Applied Chemistry and Chemical Engineering, Faculty of Engineering and Technology, University of Dhaka,
BANGLADESH

M. A. Gafur
Pilot Plant and Process Development Center, Bangladesh Council of Scientific and Industrial Research, Dhaka
BANGLADESH

Ruhul A. Khan
3Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Savar, Dhaka,
BANGLADESH

ABSTRACT

China clay reinforced polyester nanocomposites were successfully fabricated by open molding method. Different percentage of nanoclay and polyester resin with a fixed percentage of styrene monomer (10 weight percent of polyester resin) was taken to prepare nanocomposites. Mechanical properties such as compressive, flexural and tensile strength, and rebound hardness of composites were investigated. Results indicated that the flexural and tensile strength of the composites decreased and E-modulus increased with the increase of clay content. Compressive strength and rebound hardness were increased with the increase of clay content in the composites.

Keywords: Composites, Polyester, China clay, Mechanical properties, Nanocomposites.

INTRODUCTION

Composites are one of the most widely used materials due to their adaptability to different situations and the relative simplicity of combination with other materials to serve specific purposes and desirable properties. Composite materials gained much attention because of their wide applications in many fields such as civil, industrial, military, air and space crafts, automobiles, and packaging applications due to their excellent thermo-mechanical properties [1-3].

Nanocomposites are composites in which at least one of the phases possesses dimensions in the nanometer range. In the last 20 years, the development of polymeric nanocomposites containing at least one of the dimensions of the filler material in the nanometer range gains much interests. Nanocomposite materials have appeared as suitable alternatives to overcome limitations of microcomposites and monolithic. It is possible to prepare nanocomposite materials with unique combination of properties which is unachievable with traditional composite materials. The improvements in mechanical properties of nanocomposites are very important due to their numerous automotive and general/industrial applications. Nanocomposites are utilized as mirror housing on various types of vehicles, door handles, engine covers, and belt covers. Other applications include: packaging, fuel cell, solar cell, fuel tank, plastic containers, impellers and blades for vacuum cleaners, power tool housing, and cover for portable electronic equipment such as mobile phones and pagers [4-8].

Polyester matrices have been used for the longest period in the widest range of structures because of easy handling, balanced mechanical and chemical characteristics, and a cheap price. In this study, unsaturated polyester resin was preferred because of their good range of mechanical properties, relatively low cost, corrosion resistance and low molecular weight. Therefore, polyesters are suitable for a variety of applications and are adaptable to the fabrication of large structures [9-12].

Polymers can be reinforced with different fillers. Filler and matrix interaction plays an important role to increase mechanical properties of the virgin polymer [13]. Clays are the oldest and potentially one of the most interesting and versatile fillers. Polymer composites filled with mineral clays are becoming attractive because of their wide applications and low cost [14]. It has been shown that dramatic improvements in mechanical properties can be achieved by incorporation of a few weight percentages (weight %) of clay minerals in polymer matrices [15-19]. Using clay minerals as reinforcements, polyester resin has continued to be used in constructional applications. The aim of this study is to prepare polyester resin/china clay nanocomposites by open molding method and to investigate the mechanical behavior of nanocomposites reinforced with various percentages of china clay by measuring the compressive, flexural and tensile strength, and rebound hardness.

METHODOLOGY

Materials

The chemicals needed for nanocomposite fabrication are polyester resin, china clay, styrene monomer and methyl ethyl ketone peroxide (as hardener). The polyester resin (number average molecular weight 2200, Boiling point 154°C and Specific density 1.194 kg/m3) was purchased from Zhejiang Tianhe Resin Company Limited, China and Styrene monomer was from Pon Pure Chemical Private Limited, Bangladesh. China clay was collected from Bangladesh Institute of Glass and Ceramics (BIGC), Bangladesh. All were collected from the local market.

Preparation of Samples

China clay was grinded (dry grinding) in a planetary ball mill (Model PM 100) to reduce the particle size to the nano range. The size of the china clay varied from a minimum of about 0.5 micron to a maximum of 74 microns. The average diameter for the individual clays varied from 1.5 to 38 microns. Then the size of the clay reduced to nano level. Different percentage of nanoclay and polyester resin with a fixed percentage of styrene monomer (10 wt% of polyester resin) was taken to prepare nanocomposites. Nanoclay was taken from 30 to 50 wt%. Table 1 shows different percentages of samples.

Table 1: China clay- Polyester composites with constant wt% of styrene monomer.

Sample	Nanoclay (%)	Polyester resin (%) (with 10% styrene monomer)
Sample-1	0	100
Sample-2	30	70
Sample-3	40	60
Sample-4	50	50

Definite amount of various percentages of nanoclay, polyester resin and styrene monomer was weighed and the raw materials were then mixed very properly with a magnetic stirrer for about half an hour. Ethyl methyl ketone peroxide was used as a hardener, as an amount of 1.5 wt % of polyester resin and styrene weight. The mixture was then poured into the open molds and kept for 4-5 hours for drying. After drying the nanocomposite was released from the mold by applying pressure. Milot paper sheet was used to smoothen the sides of the nanocomposite. Figure 1 shows an image of china clay/polyester resin nanocomposite.

Figure 1: Image of china clay/polyester resin nanocomposite

Mechanical Characterization

To evaluate the mechanical properties of prepared nanocomposites, some tests were performed. Flexural strength was tested to determine the ability of nanocomposites to resist deformation under load; compressive strength test was performed to measure the capacity of nanocomposites to withstand loads tending to reduce size. Tensile strength of nanocomposites was tested to observe their behavior when subjected to a controlled tension until failure. Rebound hardness test was performed to measure the resistance of nanocomposites to various kinds of permanent shape change when a compressive force is applied. Test specimens were prepared according to the ASTM standard measurements. The flexural, compressive and tensile strengths of the nanocomposites were determined by Universal testing machine (Model 1011UK, INSTRON Corporation). The rebound Hardness was measured by Leeb Rebound Hardness Tester (Model H1000).

RESULTS AND DISCUSSION

Flexural Test

The effects of addition of nanoclay on flexural strength of polyester resin/china clay nanocomposites were illustrated in Figure 2. It reveals that the flexural strength decreases with the addition of clay to the polymer matrix. The flexural strength of the nanocomposites is lower than that of polyester resin, so these nanocomposites are brittle. The decrease in flexural strength of nanocomposites on increasing the volume fraction of clay is due to the weakening of clay under tension. Flexural strength obtained for unsaturated polyester resin was almost similar to the result of the reported values [18].

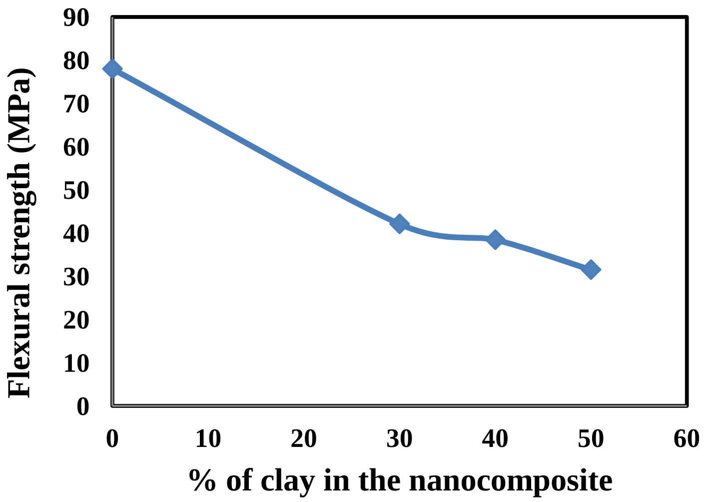

Figure 2: Effect of addition of clay on flexural strength for china clay/polyester resin nanocomposites

E-Modulus (Elastic Modulus)

Figure 3 illustrates the E-Modulus of polyester/china clay resin nanocomposites by the addition of different wt% of clay. It is seen that the E-Modulus of nanocomposites increases with the increase in amount of clay due to high degree of adhesion between the polymer and clay [19].

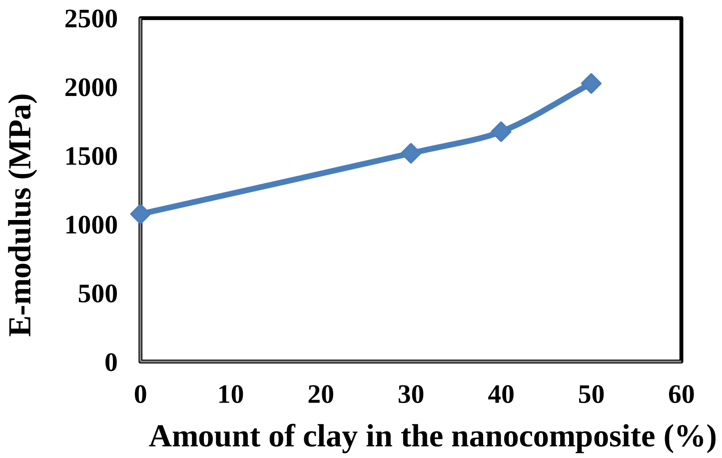

Figure 3: Effect of clay addition on E-Modulus of china clay/polyester resin nanocomposites

Compressive Strength

The effects of addition of clay on compressive strength for polyester resin/china clay nanocomposite are represented in Figure 4. Results indicate that compressive strength of nanocomposite is lower than that of polyester resin. At first the value increases with increasing percentage of clay up to 40% and then decreases with the increase of clay. Up to 40% of nanoclay, the compressive strength increases due to high degree of adhesion between the polymer molecules and clay particles, because the clay acts as a binding material, while for higher percentage of clay the compressive strength decreases as the clay particles extend the distance between the polymer molecules, i.e. break the intermolecular forces between these molecules. Compressive strength obtained for unsaturated polyester resin was in good agreement with the result of Sultana [18].

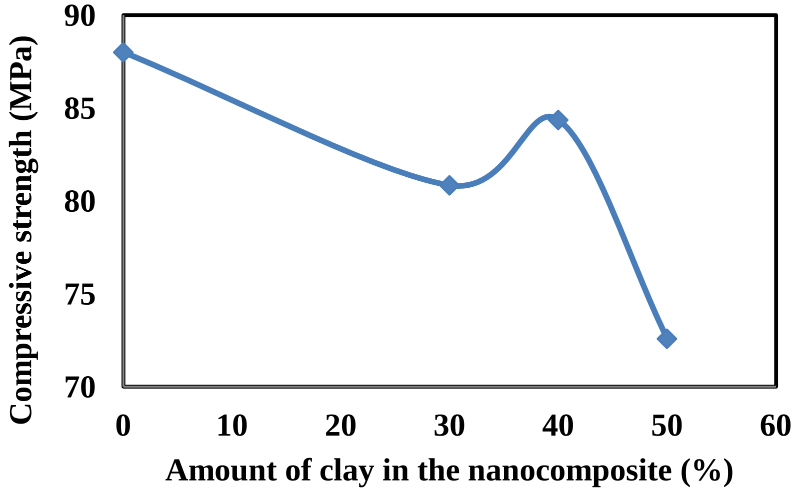

Figure 4: Effect of addition of clay on compressive strength of china clay/ polyester resin nanocomposites

Young's Modulus

Figure 5 shows the Young's Modulus of china clay/polyester resin nanocomposites as a function of different clay percentage added to it. It can be found that the Young's modulus of nanocomposite is less than that of polyester resin. For nanocomposites, the value increases with an increase in clay content (up to 40% china clay). Further addition of clay decreases Young's Modulus.

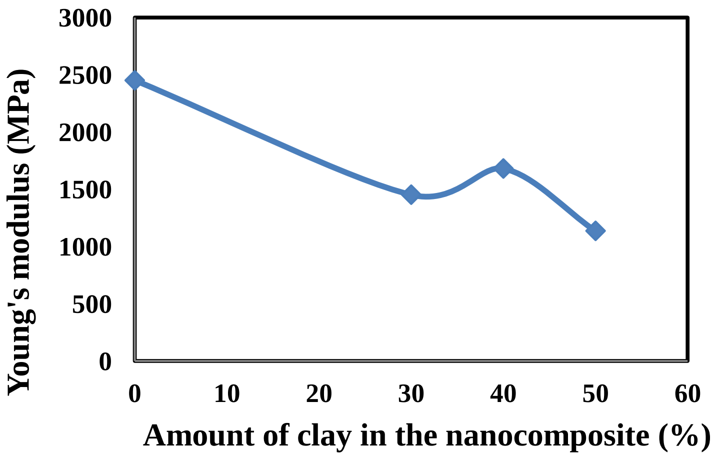

Figure 5: Young's Modulus of china clay/polyester resin nanocomposites by addition of different clay percentage

Tensile Strength

Figure 6 illustrates the effect of addition of clay on tensile strength for china clay-polyester resin nanocomposites. It is seen that, the tensile strength of nanocomposites are lower than that of polyester resin. The value decreases with the increase in amount of clay in the nanocomposite. The decrease in tensile strength can be attributed to the physical properties of this filler (clay) and interaction of this filler with the polymer matrix [20].

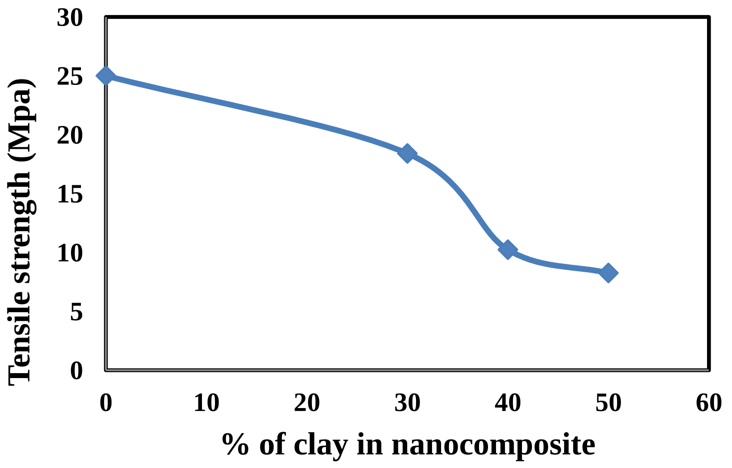

Figure 6: Tensile strength of china clay-polyester resin nanocomposites by addition of different % of clay

Percentage Elongation

Figure 7 illustrates the effect of addition of clay on percentage elongation for china clay-polyester nanocomposites. It is observed that the elongation of nanocomposites decreases with the increase in clay content. This is due to the reduction of matrix volume [21], since the elastic properties are only obtained from the matrix [22]. This indicates that incorporation of nanoclay in polymer matrix reduces the elasticity of the matrix, which leads to more rigid nanocomposites.

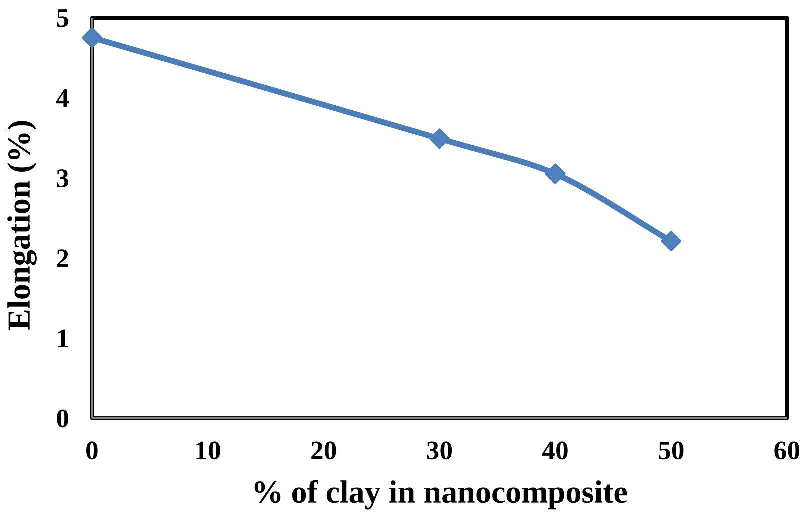

Figure 7: Elongation percentage of china clay-polyester nanocomposites by addition of different percentage of clay

Rebound Hardness

The effect of addition of clay on rebound hardness for china clay-polyester nanocomposites was illustrated in Figure 8. It reveals that the rebound hardness of nanocomposite is higher than that of polyester resin and this value increases with the addition of clay up to 40%. If more than 40% clay is added, then rebound hardness of nanocomposite starts to decrease. At lower percentage of filler it acts as binder while at higher percentage it causes reduction in density of polymer matrix [19].

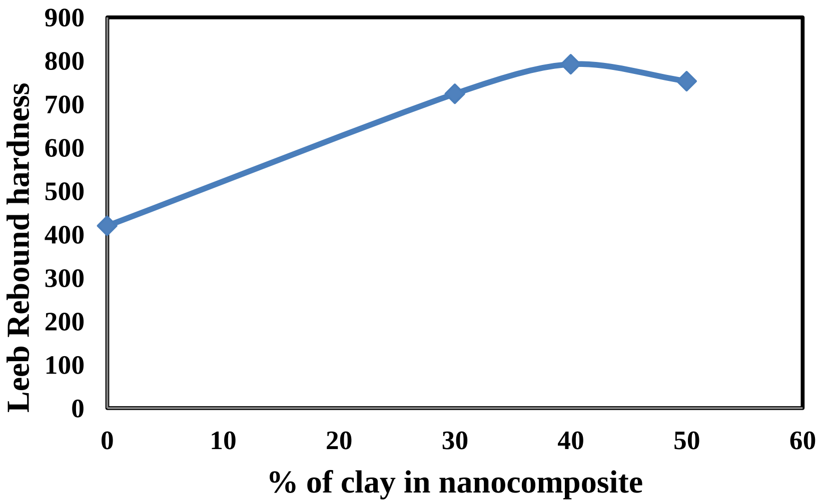

Figure 8: Rebound Hardness of china clay-polyester resin nanocomposites by addition of different percentage of clay

CONCLUSIONS

China clay reinforced polyester nanocomposites with good mechanical properties can be successfully fabricated by open molding method. Varying amount of china clay filler is important parameter of this fabrication process. Significant change occurs in the mechanical characteristics of nanocomposites while changing the percentage of clay content in it. Flexural strength of china clay/polyester nanocomposites decreases constantly with an increase in clay content. But the E-modulus of nanocomposite increases with the addition of clay constantly. The flexural strength is lower than that of polyester resin, so these nanocomposites are more brittle. The compressive strength of nanocomposites is lower than that of polyester resin. Among the nanocomposites, the value of compressive strength increases with increase in the amount of clay up to 40% and then decreases with increasing clay content. Tensile strength of nanocomposites decreases with increase in clay content. Rebound hardness of nanocomposites was found to increase with increasing amount of clay up to 40% clay addition and then it decreases with increasing clay percentage.

ACKNOWLEDGEMENTS

The authors are thankful to Centre for Advanced Research in Sciences (CARS), University of Dhaka for providing additional research facilities.

REFERENCES

[1] Kafi A, Abedin MZ, Beg MDH, Pickering KL, Khan MA.(2006) Study on the mechanical properties of jute/glass fiber-reinforced unsaturated polyester hybrid composites: Effect of surface modification by ultraviolet radiation. *J Reinfor Plast Compo*; *25*,575-588. http://jrp.sagepub.com/content/25/6/575.full.pdf+html

[2] Khan RA, Khan MA, Sultana S, Khan MN, Shubhra QTH, Noor FG. (2010) Mechanical, Degradation and interfacial properties of synthetic degradable fibre reinforced polypropylene composites. *J Reinfor Plast Compo*, *29*,466-476. http://jrp.sagepub.com/content/early/2009/02/23/0731684408100699.full.pdf+html

[3] Hattum FWJ, Regel F, Labordus M. (2011) Cost reduction in manufacturing of aerospace composites. *Plast Rubber Compos*, *40*,93-99. http://www.maneyonline.com/doi/pdfplus/10.1179/174328911X12988622801052

[4] Roy R, Roy RA, Roy DM. (1986) Alternative perspectives on "quasi-crystallinity": Non-uniformity and nanocomposites. *Mat Lett*, *4(8)*, 323-328. http://ac.els-cdn.com/0167577X86900637/1-s2.0-0167577X86900637-main.pdf?_tid=81998076-00c0-11e5-adfa 00000aab0f6b&acdnat=1432326431_e78ab8c46c51827bdeb91305d54e07cb

[5] Hussain F, Hojjati M, Okamoto M, Gorga RE. (2006) Review article: polymer-matrix nanocomposites, processing, manufacturing, and application: an overview. *J Compos Mat*, *40*,1511-1575. http://jcm.sagepub.com/content/40/17/1511.full.pdf+html

[6] Manocha L, Valand J, Patel N, Warrier A, Manocha S.(2006) Nanocomposites for structural applications. *Indian J Pure and Appl Phys*, *44*, 135-142. http://nopr.niscair.res.in/bitstream/123456789/8249/1/IJPAP%2044%282%29%20135-142.pdf

[7] Anandhan S, Bandyopadhyay S. (2011) Polymer Nanocomposites: From Synthesis to Applications. J Nanocomp Polym Anal Met, 630-636. http://www.intechopen.com/books/nanocomposites-and-polymers-with-analytical-methods/polymer-nanocomposites-from-synthesis-to-applications

[8] Khan RA, Khan MA, Zaman HU, Pervin S, Khan N, Sultana S, Saha M, Mustafa AI. (2010) Comparative Studies of Mechanical and Interfacial Properties Between Jute and E-glass Fiber-reinforced Polypropylene Composites. J Rein Plast Compost, *29(7)*, 1078-1088. http://jrp.sagepub.com/content/29/7/1078.full.pdf+html

[9] Mishra S, Mohanty AK, Drzal LT, Misrab M, Parija S, Nayak SK, Tripathy SS. (2003) Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites. *J Compos Sci Techo* , *63(10)*, 1377–1385 http://www.sciencedirect.com/science/article/pii/S0266353803000848

[10] Rong MZ, Zhang MQ, Liu Y, Yang GC, Zeng HM. (2001) The effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites. *J Compos Sci Techol*,*61(10)*, 1437-1447.

[11] John K, Nnaidu SV.(2004) Tensile properties of unsaturated polyester-based sisal fiber–glass fiber hybrid composites. *J Rein Plast Compos*, *23(17)*, 1815-1819. http://jrp.sagepub.com/content/23/17/1815.full.pdf+html

[12] Hussein MA, Rozman HD, Tay GS. (2013) The effect of kenaf fibre loadings on the properties of UV-cured unsaturated polyester composites. *J Rein Plast Compos*, *32(14)*, 1062-1071. http://jrp.sagepub.com/content/32/14/1062.full.pdf+html

[13] Lei S, Hoa SV, Ton-That MT. (2006) Effect of clay types on the processing and properties of polypropylene nanocomposites. *Compos Sci Technol*, *66*,1274-1279. http://ac.els-cdn.com/S0266353805004008/1-s2.0-S0266353805004008-main.pdf?_tid=5f5ac48c-00c2-11e5-b568-00000aab0f26&acdnat=1432327232_a346396422f4b72688a710382beac613

[14] Unal H, Fındık F, Mimaroglu A.(2003) Mechanical behavior of nylon composites containing talc and kaolin. *J Appl Polym Sci*, *88*,1694-1697. http://onlinelibrary.wiley.com/doi/10.1002/app.11927/pdf

[15] Ho KM, Park CI, Choi WM, Lee JW, Lim JG, Kim JM. (2004) Synthesis and material properties of syndiotactic polystyrene/organophilic clay nanocomposites. J *Appl Polym Sci*, *92*, 2144-2150. http://onlinelibrary.wiley.com/doi/10.1002/app.20186/pdf

[16] Sinha Ray S, Okamoto M. (2003) Polymer/layered silicate nanocomposites: A review from preparation to processing. *Progress in polymer science*,*28*,1539-1641.

ISSN 2398-1385

http://ac.els-cdn.com/S0079670003000790/1-s2.0-S0079670003000790-main.pdf?_tid=1027b932-00c8-11e5-a144-00000aab0f01&acdnat=1432329676_cd4d7321630193d42cd04de3761748c0

[17] Zhang YH, Wu JT, Fu SY, Yang SY, Li Y, Fan L, Yang Q. (2004) Studies on characterization and cryogenic mechanical properties of polyimide-layered silicate nanocomposite films. *Polymer, 45*, 7579-87. http://ac.els-cdn.com/S0032386104007797/1-s2.0-S0032386104007797-main.pdf?_tid=5e5cb85a-00c8-11e5-a5ce-00000aab0f02&acdnat=1432329808_73369329cb5dd3e7fa8ba3ed978361ea

[18] Sultana R, Akter R, Alam MZ, Qadir MR, Begum MA, Gafur MA. (2013) Preparation and characterization of sand reinforced polyester composites. *Int J Eng Technol,13(2)*,111-118.http://www.ijens.org/Vol_13_I_02/135202-4747-IJET-IJENS.pdf

[19] Zhang M, Bin L, Sundararaj U. (2012) Effects of processing sequence on clay dispersion, phase morphology, and thermal and rheological behaviors of PA6-HDPE-Clay nanocomposites. *J Appl Polym Sci*, *125*, 714–724. http://onlinelibrary.wiley.com/doi/10.1002/app.36692/pdf

[20] Moczo J, Pukanszky B. (2008) Polymer micro and nanocomposites: structure, interactions, properties. *J Indust Eng Chem,14*,535-563. http://www.sciencedirect.com/science/article/pii/S1226086X08001032

[21] Suradi SS, Yunus RM, Beg MDH. (2011) Oil palm bio-fibre-reinforced polypropylene composites: effects of alkali fibre treatment and coupling agents. *J Compo Mater, 45*,1853-1861. http://jcm.sagepub.com/content/45/18/1853.full.pdf+html

[22] Firoozian P, Akil HM, Khalil HA. (2010) Prediction of mechanical properties of mica-filled epoxy composite using various mechanical models. *Journal of Reinforced Plastics and Composites*,29,2368-2378. http://jrp.sagepub.com/content/29/15/2368.full.pdf+html